Science & Technology Facilities Council

WORKING WITH LASERS

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Working with Lasers

1. Purpose

Lasers emit beams of non-ionising radiation at wavelengths spanning the ultraviolet to the far infrared. The skin and eyes are at risk of injury; thermal burns from visible or infrared laser beams or photo-chemical burns from ultraviolet laser beams. For lasers in the visible or near infrared part of the spectrum there is a particular risk of damage to the retina of the eye, resulting in permanent visual impairment. The power of laser beams, particularly pulsed lasers, can be so high that not only the main beam but also weak reflections and diffusely scattered radiation can be hazardous.

Lasers are a flexible research tools which enjoy wide use across all disciplines. For lasers whose output presents a significant risk of harm, this flexibility and breadth of use combined with continuing evolution (e.g. higher output from physically smaller devices) creates unique challenges to the control of the laser hazard, in many cases preventing a rigid prescriptive approach to laser safety and relying instead on detailed risk assessment, a mix of engineering and administrative control, and laser safety eyewear to address residual risks.

2. Scope

This Code is applicable to all staff, contractors, users and tenants working with lasers at STFC sites.

There are no health and safety regulations specific to the safe use of lasers, but there is an international user guide TR 60825-14: 2004 ‘Safety of laser products: Part 14 - A user’s guide’ which sets out current best practice.

This Code embodies the guidance provided in TR 60825-14, translating its general guidance into STFC requirements and defining the responsibilities of those persons appointed to carry out specific laser safety duties. The Code does not address the compliance issues for the laser manufacturer covered in EN 60825-1:2007 ‘Safety of laser products: Part 1- Equipment classification and requirements’. Other relevant laser safety references are listed in Appendix 17.

This Code deals principally with the beam hazards of using lasers (see Appendix 1); it refers to but does not deal with associated (non-beam) hazards of laser use, including electrical, chemical and secondary radiation hazards. These hazards are described in more detail in Appendix 2, and details of safety precautions relating to these hazards can be found in the relevant SHE Safety Codes.

Risk assessment plays a particularly important part in the selection of appropriate laser hazard control measures. The general Risk Assessment process, SHE Code 6 ‘Risk Management’ applies, but should be implemented in conjunction with the guidance provided in Appendix 11.

3. Definitions

3.1 High Risk lasers
Class 3B and 4 laser products.

3.2 Low Risk lasers
Embedded, Class 1M, 2, 2M and 3R laser products.

3.3 No Risk lasers
Intrinsic Class 1 laser products and Class 1 consumer products that contain a laser of a higher class (e.g. desk top laser printer, LED printer or photocopier, compact disc or DVD player or recorder) which are serviced only off site.

3.4 Embedded lasers
Laser products that contain a Class 3B or Class 4 laser but which, because of engineering features limiting accessible emissions, have been assigned as Class 1. However if these lasers are to be aligned, modified or serviced on site then additional precautions need to be taken as laid out in Appendix 6.

3.5 Overall Laser Responsible Officer (OLRO)
A competent person appointed by the authority of the Director or equivalent, to oversee the control of laser radiation hazards and to be responsible for the implementation of this Code with respect to a defined area of laser installations and/or equipment.

3.6 Laser Responsible Officer (LRO)
A competent person appointed to take on specified duties and supervisory responsibilities in respect to a laser area or activity.

3.7 Laser Nominated Person (LNP)
A competent person appointed to carry out specified laser work.

3.8 Laser Protection Adviser (LPA)
A competent person, knowledgeable and experienced in laser safety matters, who is called upon to assist the OLRO in the performance of his or her duties. The LPA may be an employee or an external consultant.

See Appendix 3 for a detailed explanation of laser classes

A more comprehensive list of relevant technical terms can be found in Appendix 14.

4. Duties and Responsibilities

4.1 Directors shall:

4.1.1 Establish a structure of responsible persons, as described below, to manage safety when working with lasers. These appointments can be made within a single department, several departments or across a whole site.

Appointments

4.1.2 Delegate the implementation of laser safety responsibilities in one of the following ways, dependent on the size and complexity of laser activities:

- Appoint a single person to take on the duties of Overall Laser Responsible Officer (OLRO).
- Appoint more than one OLRO provided that the duties of each do not overlap. Such an option might be useful, for example, if there are several major groupings of laser activities.
- Combine the duties of the OLRO with those of a Laser Responsible Officer (LRO). This option might be appropriate if there is only one small laser activity.

4.2 Line Managers and Supervisors shall:

4.2.1 Ensure that the requirements of this Code are met with regard to laser work for which they are responsible.

Appointments

4.2.2 Appoint (in conjunction with the OLRO) one or more Laser Responsible Officers (LROs) and deputies as appropriate, to provide day-to-day supervision of all High Risk (see Section 3.1) laser activities. Where more than one LRO is appointed, their duties must not overlap. Line managers and supervisors may take on the role of LRO.

Control of changes to laser work

4.2.3 Ensure that before significant changes are made to laser activities (e.g. additional High Risk lasers, major reorganisation of laser layouts etc): an outline safety case is prepared; adequate facilities are available for safe use; and the necessary documentation is prepared and submitted to the OLRO.

Training for users of Low Risk lasers

4.2.4 Ensure that persons working with Low Risk lasers, for which no LRO is responsible, receive sufficient training in the safe use of lasers (See Appendix 15).

4.3 Overall Laser Responsible Officers shall:

4.3.1 Implement this Code within the scope of their letter of appointment. This includes the following duties, which may be undertaken with the assistance of a Laser Protection Advisor:

Advice

4.3.2 Advise and liaise with the Director, Line Managers and Supervisors on laser safety matters.

4.3.3 Advise Line Managers and Supervisors on the appointment of LROs, particularly with regard to the scope of their approved activities.

4.3.4 Advise and support LROs in the discharging of their laser safety responsibilities.

Incidents and accidents

4.3.5 Assist the Director, Line Managers and Supervisors in the investigation of any laser-related safety incidents.

4.3.6 Establish procedures to ensure that in the event of an apparent or suspected laser injury to the eye, a medical examination by a qualified ophthalmologist is carried out within 24 hours.

Arrangements

4.3.7 Ensure that arrangements are in place for: training LROs and LNPs (Appendix 15); laser classification (if appropriate); inspection of new laser facilities; and regular audits of laser areas.

Control of changes in laser use

4.3.8 Review outline safety cases for the acquisition or major reorganisation of High Risk laser equipment.

4.3.9 Review laser safety implementation before and after commissioning of new or significantly changed High Risk laser equipment, checking that the necessary laser safety documentation as set out in Appendix 12 has been updated accordingly.

Relaxations of the Code

4.3.10 Approve discretionary relaxations from requirements of this Code provided justification is made in writing by the LRO and approved by the responsible Line Manager or Supervisor.

Inspections

4.3.11 Undertake/arrange regular (every 18 months) inspection/audit of High Risk laser activities as set out in Appendix 16.

4.3.12 Distribute the reports of inspections and audits as appropriate e.g. to Director, safety committees, Line Managers or Supervisors, LROs, SHE Group etc.

4.3.13 Monitor the recommendations/findings, from any inspections and audits against deadlines for completion.

4.4 Laser Responsible Officers shall:

4.4.1 Take on specified duties and responsibilities for the day-to-day implementation of this Code for the laser area and/or activity for which they have been appointed.

Appointments and training

4.4.2 Where appropriate, appoint Laser Nominated Persons (LNPs) to undertake specific tasks, setting out in writing, prior to commencement of their work, the constraints on their activities. LNPs may be given specific titles (e.g. Target Area Operator, Visiting Laser User) if this helps clarify their role.

4.4.3 Provide on the job training to all LNPs before they begin laser work, including a review of Standing Orders.

4.4.4 Approve the proposed work of LNPs and the laser/experimental arrangements and activities prior to commencement of their work.

4.4.5 Ensure that LNPs are suitably supervised when carrying out their work and where appropriate rescind their appointment in the event of cases of breaches in safe practice.

4.4.6 Ensure that all those working with High Risk lasers are aware of the procedures for real or suspected eye injuries (see Appendix 10).

Establishing safe working with High Risk lasers

4.4.7 Identify both the beam hazards (Appendix 1) and the non-beam hazards (Appendix 2) and produce a risk assessment and Standing Orders for each work area or activity (Appendices 11, 12).

Based on the results of the risk assessment:

4.4.8 Establish a Designated Laser Area (Appendix 7).

4.4.9 Implement controls for normal laser operation (Appendix 5).

4.4.10 Implement additional controls for specific High Risk laser activities (Appendix 6).

4.4.11 Ensure the proper design and placement of laser safety labels (Appendix 8).

4.4.12 Ensure availability of appropriate laser safety eyewear and its proper storage and maintenance (Appendix 9).

Changes in laser work

4.4.13 Before implementing major changes in a Designated Laser Area or making significant changes to laser activities (e.g. additional High Risk lasers, major reorganisation of laser layouts etc), prepare and submit an outline safety case to the OLRO.

4.4.14 After completion of the changes, complete and submit to the OLRO the new/revised risk assessment and standing orders prior to first operation.

4.4.15 Ensure that devices with the capability to emit laser radiation, which have not already been classified by the manufacturer to EN 60825-1, have their classification confirmed prior to first use on site. Until such confirmation is obtained, the device should be treated as Class 4. N.B. The use of OEM lasers, which are supplied without safety features for the purpose of incorporation into another piece of equipment, raises a particular problem in this regard.

Documentation

4.4.16 Prepare full laser safety documentation (Appendix 12).

4.4.17 Keep all laser safety documentation up to date, review the documents at least annually and forward copies of reissued documents to the Line Manager or Supervisor.

4.4.18 Maintain lists of Laser Nominated Persons.

4.4.19 Ensure that Standing Orders for an area are made readily available to users of the area.

4.4.20 For LNPs about to undertake laser work, ensure that the methods, procedures and aims are first agreed and that signatures to this agreement are obtained.

4.4.21 Issue Permits to Work.

4.5 Laser Nominated Persons (staff, tenant, user or contractor) shall:

4.5.1 Be familiar with and abide by the Standing Orders for the area in which they work, and follow the prescribed procedures for the equipment that they are using.

4.5.2 Work within the constraints placed upon their activities by the LRO.

4.5.3 Undertake training as requested by the LRO.

4.5.4 Not make any significant changes to laser beam paths, beam wavelengths or safety devices, nor introduce new lasers to the laboratory without the authorisation of the LRO.

4.5.5 Inform their line manager or person responsible for their health and safety of any pre-existing eye condition they may have, since this could affect the risk assessment.

4.5.6 Be conversant with and follow the procedures for real or suspected eye injuries (see Appendix 10)

Appendix 1. Beam hazards associated with laser use

Over the wavelength range that different lasers operate, the skin is a strong absorber, thereby protecting all the organs of the body except for the eyes.

A1.1 Injury mechanisms

There are three principal types of tissue damage mechanisms for laser radiation: thermal, photo chemical and thermo-mechanical. The predominant injury mechanism is determined principally by the laser wavelength, the duration and the irradiance of tissue exposure

A1.2 Ocular injuries

The biological effects on the eyes at different wavelengths are:

	Wavelength range	**Primary tissue at risk of damage**
Ultraviolet	180 nm - 400 nm	Cornea or lens (302-315 nm)
Visible Near Infra-red	400 nm - 1.4 μm	Retina
Medium & Far Infra-red	1.4 μm - 1 mm	Cornea or lens (1.4 – 3.0 μm)

Retinal eye damage from laser radiation can occur at very low power levels due to the focusing effect of the cornea and lens of the eye and the coherence of laser radiation.

In a research laboratory there may be lasers operating at different wavelengths, fixed and variable, from the UV through the visible and IR. What may seem to be a steady beam may be a pulsed laser operating at a high pulse repetition rate with peak powers in the individual pulses that are more than a million times the average power of the beam. Apparently weak blue or red beams may be operating at wavelengths at the extreme of the visual response range of the eye where its sensitivity is several thousand times below its peak sensitivity (yellow light). UV and IR beams cannot be seen at all.

The Maximum Permissible Exposure (MPE) represents a safe level of exposure to laser radiation; it varies with wavelength range and duration of exposure. For example, for a 30000s exposure (a working day of approximately 8 hours) the MPE for intra-beam viewing of laser radiation is $10 Wm^{-2}$ in the range 315-400nm where the UV light is absorbed by the lens of the eye. In the visible region where the lens of the eye brings the radiation to a focus on the retina, the MPE is very much lower e.g. 0.01 Wm^{-2} in the range 400-550nm; this arises because the eye can focus such radiation to a spot of diameter as little as 20μm on the retina, corresponding to an increase in power density of 10^5 - 10^6.

Damage to the eye can arise from different mechanisms depending on the duration of exposure to the light. In particular, for very short exposures (< 10^{-6} s), damage arises

from thermo-acoustic transients. Simple heating effects predominate in the range 100ms - 10s and for exposures longer than 100s photo-chemical effects can predominate for wavelengths less than 600 nm. These different processes make the determination of safe radiation levels for pulsed lasers a complicated task that requires a detailed study of the MPE tables.

A1.3 Injuries to the skin

The biological effects of skin exposure to laser radiation are simpler to assess than those for the eye. The injury is surface burning which may occur following acute exposure to cw laser beam. This can occur in a fraction of a second for a beam of powers 0.5W or more; or over a prolonged period for photo-chemical burns from ultraviolet laser beams. Unlike retinal eye burns, skin burns may easily be treated. They are sterile and generally heal quickly.

In the visible and near infrared wavelength range, the MPE for > 10s skin exposure is $1000 Wm^{-2}$, similar to the solar constant of $1400 Wm^{-2}$. In the UV the MPE for skin exposure is identical to that for eye exposure.

Laser damage mechanisms for skin tissue are similar to those for the eye in terms of the effect of wavelength and exposure duration.

Appendix 2. Non-beam hazards associated with laser use

In addition to the direct laser radiation hazard, a laser can present other hazards, all of which need to be considered in a risk assessment of laser use. The tables that follow list some of the more common or these non-beam or associated hazards together with some typical situations where they arise and typical control measures.

A 2.1 Hazards arising from the laser source

Hazard	Typical hazardous situation	Typical control measures
High voltage	Laser head and power supply exposed during servicing. Many lasers utilise high voltages, and pulsed lasers frequently employ capacitors to store electric charge.	Proper screening of exposed HV. Restricted access to qualified persons. Use of earthing stick to ensure the removal of stored energy prior to commencement of servicing work.
Fire and Explosion	Laser equipment can present a fire hazard by virtue of the flammable components, plastic parts etc. contained within it, which can overheat or catch fire in the event of a fault within the equipment. High-pressure flash lamps, capacitors and other internal components can explode.	For fire: provision of a fire extinguisher; smoke alarm; training. For explosion protection during maintenance activities: gloves and face shield; training.
Noise	The discharge of capacitor banks within the laser power supply can generate noise levels high enough to cause ear damage. Ultrasonic emissions and repetitive noise from pulsed lasers can also be harmful.	Use of ear protectors where excessive noise levels cannot be eliminated.
Collateral radiation	Ultraviolet, visible and infrared emission can be produced from gas laser discharge tubes. Microwave and radio frequency radiation is produced in RF-excited lasers, and can be emitted by the equipment if not properly shielded during servicing. X-rays can be produced by high-voltage thermionic valves within the laser power supply.	Proper screening combined with access restricted to service engineers.
Mechanical	Unloading and positioning of laser power supplies and ancillary items such as gas cylinders. Trailing cables and water-circulation tubing can present a trip hazard.	Provide attachment points for use of lifting equipment by qualified persons. Training and use of gloves. Properly secure equipment. Cover cables in ducting or under a raised walkway.
Chemical	The material used as the active medium in many lasers (especially laser dyes and the gases used in excimer lasers) can be toxic and carcinogenic. The solvents used in many dye lasers have the ability to carry their solutes through the skin into the body. They may also be highly volatile and should not be inhaled.	Proper storage, handling and disposal precautions should be adopted. Training and use of gloves and other PPE.

A 2.2 Hazards arising from the laser process

Hazard	Typical hazardous situation	Typical control measures
Fume	Release of hazardous particulate and gaseous by-products into the atmosphere through the interaction of the laser beam with the target material during laser materials processing and laser surgery.	General precautions include: Fume extraction and filtration. Face mask and gloves worn during cleaning operations.
Hazardous substances	Cleaning solutions and also other materials used in conjunction with the laser (e.g., zinc selenide lenses) may be hazardous.	Use proper storage and implement handling and disposal precautions.
Fire and explosion	The laser emission from high-power (Class 4) lasers can ignite target materials. These effects are enhanced in the oxygen-rich environment utilised in some laser processing applications. Laser emission from even lower-class lasers, especially when concentrated over very small areas, can cause explosions in combustible gases or in high concentrations of airborne dust. Improperly terminated Class 4 laser radiation.	Control flammable materials and beam path. Provide a fire extinguisher in the laser area.
Secondary radiation	X-ray, UV and blue light emitted by the plasma that can be generated by interaction of the laser beam (particularly those containing short, high power pulses) with target materials. Such emissions can include x-rays, ultraviolet radiation (UV), visible light, infrared radiation (IR), microwave radiation and radio-frequency (RF) radiation.	Enclose target area and monitor hazard. Wear PPE for exposure to UV and blue light.
Mechanical	Beam delivery arms and robotic systems that move under remote control can cause serious injury. Large work-pieces (such as sheet metal) can present manual handling problems such as cuts, strain, and crush injuries.	Guard traps and add warning signs. Restrict access to moving parts.

A 2.3 Hazards arising from the laser environment

Hazard	Typical hazardous situation	Typical control measures
Temperature and humidity	Excessive high or low ambient temperatures, or high levels of ambient humidity, can affect the performance of the laser equipment, including its in-built safety features, can compromise safe operation and make the wearing of safety eyewear uncomfortable. Condensation on optical components can affect beam transmission through the system.	Provide air conditioning and humidity control of the local environment. Install a gas purge in beam delivery line.
Mechanical shock and vibration	Misalignment of the optical path, generating hazardous errant beams.	Install a vibration isolation system on the legs of optical tables holding optical components. Construct a floating foundation for large laser machines.

Atmospheric affects	Laser ignition of solvent vapour, dust, and inflammable gases present in the environment.	Enclose beam and process zone and add a gas purge. Install gas sensors to detect presence of inflammable gases and vapours.
EM and RF interference	Compromised operation of control circuits caused by interference to laser equipment resulting from exposure to EM radiation and high voltage pulses conducted down supply or data cables.	Screen equipment and filter supply and data cables.
Power supply interruption or fluctuation	Interruption or fluctuation of the electrical supply can affect the operation of the laser's safety system.	Install a voltage regulation system and back-up supply.
Computer software problems	Serious and unpredictable hazards arising without warning caused by errors in computer programming of software control.	Use only approved protocols for software control of safety functions.
Ergonomic and human-factor considerations	Poor arrangement of the physical layout of the laser and its associated equipment. Lack of space resulting in a cluttered environment. Complex or difficult operating procedures. Human factors, including: personal aspects (mental and physical attributes of the individual, including work ability , perception of workplace risks, age and experience, and attitude to safety); job aspects (tasks or functions to be performed; influence on human performance of the equipment that has to be used); organisational aspects ("safety culture" of the organisation, including the framework within which an individual has to work and the influences and pressures (real or imagined) that the individual may be under).	Improve layout, reduce clutter and review the ergonomics of repetitive or sustained tasks. Training to improve human factors since these play some part in the majority of work-related accidents.

Details of safety precautions relating to particular hazards can be found in the relevant SHE Safety Codes.

Appendix 3. Classes of laser

Lasers are classified on the basis of their accessible emission. It is the manufacturer's responsibility to classify the laser, but a user who significantly modifies a laser takes on the role of manufacturer including the responsibility to reclassify (or confirm the original classification).

For each laser class there is an Accessible Emission Limit (AEL), generally expressed in Watts or Joules, and a number of conditions of measurement under which a laser's output is to be measured for comparison with the AEL. Full details are provided in EN 60825-1: 2007 Safety of laser products: Part 1.

A3.1 Class 1

Class 1 laser products are safe in normal use under reasonably foreseeable conditions. There are two types of Class 1 laser products:

A3.1.1 Intrinsic Class 1

The laser output is safe because the output of the laser source is too low to cause harm, even if magnifiers or other such optical devices are used to modify the laser beam or assist viewing. This Code places no requirements on the use of intrinsic Class 1 lasers.

A3.1.2 Embedded laser product: safe by engineering design

Embedded laser products are ones that because of engineering safety features have been assigned a class lower than they would otherwise have. In general this means that the laser radiation is totally enclosed, preventing it becoming accessible to the user in normal operation.

In this Code the term 'Embedded' is restricted to products that are Class 1 but contain a Class 3B or Class 4 laser that is accessible in the service or maintenance operations specified by the manufacturer.

The use of Embedded laser products in general is dealt with in this Code because: (i) a degree of maintenance and care in the use of the product is required to preserve its safety; and (ii) the laser hazard may be exposed during maintenance and servicing of the product.

However, this Code places no requirements on the use of embedded laser products that are Class 1 consumer products, including desk top laser printers, LED printers and photocopiers, CD and DVD players and recorders provided they are serviced off site.

A3.2 Class 1M

Class 1M laser products are safe in normal use provided lenses and/or mirrors or other such optical devices are not used to modify the laser beam or to assist viewing. Control of unfiltered optical viewing aids is therefore generally sufficient to ensure safety.

Under the measurement conditions appropriate to Class 1, which take some account of viewing aids, the Accessible Emission Limit (AEL) for Class 1M limit is the same as for Class 3B. Although in practice it is unlikely that the Class 3B limit would be approached while still maintaining the beam safe for unaided viewing, the assumption must be made that a serious injury could result under conditions of assisted viewing or if external optics are used to change the diameter and/or divergence of the beam.

The applicability of Class 1M is restricted to laser wavelengths in the range 302.5 nm to 4 μm. This is deemed to be the reasonably foreseeable transmission range of optical viewing aids and corresponds approximately to the transmission window of fused quartz.

Class 1M lasers products are regarded as Low Risk in this Code. The use of Class 1M (collimated beam) lasers is more restrictive than Class 1M (divergent beam) because harmful exposure can occur under distant viewing with viewing aids in the case of the former but only at viewing distances of less than 100 mm for the latter.

A3.2.1 Class 1M (divergent beam)

Class 1M laser products emitting highly divergent laser beams are safe for 'naked eye' viewing (i.e. without the use of viewing aids) by virtue of the fact that at the minimum distance of accommodation of the eye (the closest distance to the laser source at which the eye can produce a clear image of the beam) the eye only collects a small fraction of the total laser output because the beam is much bigger than the pupil size. However, viewing with focussing optics such as eye loupes and magnifier (spectacles do not qualify in this regard) effectively reduces the minimum distance of accommodation and can therefore be unsafe.

A3.2.2 Class 1M (collimated beam)

Class 1M laser products emitting laser beams that are of larger diameter than the pupil size of the eye (7 mm maximum) are safe for 'naked eye' viewing (i.e. without the use of viewing aids) by virtue of the fact that the eye will only collect a small fraction of the total laser output. However, viewing with a telescope or binoculars collects light over a much greater diameter than 7 mm and can therefore be unsafe.

A3.3 Class 2

Class 2 laser products emit low levels of visible radiation (i.e. in the wavelength range 0.4 to 0.7 μm) and are safe in normal use by virtue of the natural aversion response of the eye to bright light, which is deemed to limit the duration of exposure to 0.25 s. Nevertheless they present a severe dazzle hazard. For a Continuous Wave (CW) laser the Class 2 AEL is 1 mW.

Class 2 laser products are regarded as Low Risk in this Code.

A3.4 Class 2M

Class 2M laser products emit visible radiation (i.e. in the wavelength range 0.4 to 0.7 μm) and are safe in normal use by virtue of the natural aversion response of the eye to bright light provided lenses and/or mirrors or other such optical devices are not used to modify the laser beam or to assist viewing. Control of unfiltered optical viewing aids is therefore generally sufficient to ensure safety. Nevertheless, they present a severe dazzle hazard.

Under the measurement conditions appropriate to Class 2, which take some account of viewing aids, the Accessible Emission Limit (AEL) for Class 2M limit is the same as for Class 3B. Although in practice it is unlikely that the Class 3B limit would be approached while still maintaining the beam safe for unaided viewing, the assumption must be made that a serious injury could result under conditions of assisted viewing or if external optics are used to change the diameter and/or divergence of the beam.

Class 2M lasers products are regarded as Low Risk in this Code.

As with Class 1M, Class 2M can exist in high divergence and collimated beam forms. The only difference is that Class 2M is limited to lasers with a visible output (i.e. 0.4 to 0.7 μm wavelength) and that the aversion response for bright light is taken account of in setting the Class 2M AEL. For the same reasons, we distinguish between Class 2M (divergent beam) and Class 2M (collimated beam)

A3.4.1 Class 2M (divergent beam)

Class 2M laser products emitting highly divergent laser beams in the wavelength range 0.4 to 0.7 μm are safe for 'naked eye' viewing (i.e. without the use of viewing aids) by virtue of the natural aversion response of the eye to bright light and the fact that at the minimum distance of accommodation of the eye (the closest distance to the laser source at which the eye can produce a clear image of the beam) the eye only collects a small fraction of the total laser output because the beam is much bigger than the pupil size. However, viewing with focussing optics such as eye loupes and magnifier (spectacles do not qualify in this regard) effectively reduces the minimum distance of accommodation and can therefore be unsafe.

A3.4.2 Class 2M (collimated beam)

Class 2M laser products emitting laser beams in the wavelength range 0.4 to 0.7 μm that are of larger diameter than the pupil size of the eye (7 mm maximum) are safe for 'naked eye' viewing (i.e. without the use of viewing aids) by virtue of the natural aversion response of the eye to bright light and the fact that the eye will only collect a small fraction of the total laser output. However, viewing with a telescope or binoculars collects light over a much greater diameter than 7 mm and can therefore be unsafe.

A3.5 Class 3R

Class 3R laser products are unsafe for direct viewing of the laser beam, whether in aided or unaided viewing, but for which the risk is still regarded as low.

The AEL for Class 3R is 5 times greater than for Class 1 or, for visible beam lasers, 5 times greater than for Class 2. This means that direct ocular exposure to the output of a Class 3R laser carries a low (i.e. not entirely negligible) risk of injury. This contrasts with Class 1M and 2M lasers for which naked eye viewing is safe but with viewing aids the risk of injury can be high.

The applicability of Class 3R is restricted to laser wavelengths greater than 302.5 nm, since for shorter wavelength ultraviolet the 5 times excess is deemed too great a factor for the exposure to be low risk.

Class 3R lasers products are regarded as Low Risk in this Code.

A3.6 Class 3B

Class 3B laser products are medium power devices for which direct ocular exposure is unsafe, but for which the diffuse reflection is safe under certain conditions (i.e. a minimum viewing distance of 130 mm and a maximum viewing time of 10 seconds). The beam also presents a minor skin hazard, especially when focused. For a CW laser in the visible or infrared wavelength range the Class 3B AEL is 500 mW.

Class 3B laser products are regarded as High Risk in this Code.

A3.7 Class 4

Class 4 laser products are high power devices for which even the diffuse reflection is generally hazardous. They may also cause skin burns and may present a fire hazard. There is no AEL for Class 4.

Class 4 laser products are regarded as High Risk in this Code.

Appendix 4. Summary of control measures for normal laser operation

Risk →	NO RISK	LOW RISK					HIGH RISK		
Class →	1		2	3R	1M and 2M		Class 3B	Class 4	
Requirement ↓	**Intrinsic**	**Embedded**			**high div**	**collimated**			**Reference Clause ↓**
LRO needs to be appointed							√	√	4.2.2
Registration	-	√	-	-	-	√	√	√	A12.3
Standing Orders	-	√	-	-	-	-	√	√	A12.2 A5.3.1.3
Risk assessment	-	√	-	-	-	-	√	√	A5.3.1.3
Training for normal use	-	-	√	√	√	√	√	√	A15
Restricted use of viewing aids	-	-	-	-	√	√	-	-	A5.2.3.3
Conform to basic beam path design principles	-	-	-	√	-	√	-	-	A5.2.2
Conform to restricted beam path design principles	-	-	-	-	-	-	√	√	A5.3.2.2
Control of specular reflections	-	-	√*	√*	-	√*	√	√	A5.2.3.4 (Low Risk) A5.3.3.3 (High Risk)
Use of key control	-	√	-	-	-	-	√	√	A5.2.3.2 (Low Risk) A5.3.3.1 (High Risk)
Service and maintenance restrictions	-	√	-	-	-	-	√	√	A6.2
Restricted to interlocked Designated Laser Area	-	-	-	-	-	-	√	√	A5.3.1.1 (High Risk)
Isolation of non-laser activities in normal operation	-	-	-	-	-	-	√	√	A7.3.5
Restricted multiple wavelength operation	-	-	-	-	-	-	√	√	A7.3.2
Eye check required	-	-	-	-	-	-	√	√	A10.1.1
Laser Safety Eyewear to be provided	-	-	-	-	-	-	√	√	A5.3.4.1
Protective clothing to be provided	-	-	-	-	-	-	-	√	A5.3.4.3

* visible beam lasers only

Appendix 5. Laser control measures: normal operation

A5.1 General

A5.1.1 All lasers except for No Risk laser products (see definitions in Section 3) are to be labelled in accordance with Appendix 8.

A5.1.2 Laser equipment in use must be properly maintained and serviced.

A5.1.3 Lasers must be made safe prior to disposal and dealt with appropriately if they contain hazardous materials.

A5.2 Low Risk lasers

A5.2.1 Risk assessment

Low Risk category lasers (see definitions in Section 3) can be used anywhere on site provided that the person responsible for their use implements the default control measures set out below; otherwise a risk assessment must be undertaken before use.

A5.2.2 Engineering controls

Open beam paths for Class 1M (collimated beam type), 2M (collimated beam type) and Class 3R lasers must take account of the following basic beam path design principles:

Basic beam path design principles

i. Locate horizontal beams above or below eye level

ii. No upwardly directed open beam paths

iii. Terminate the beam at the end of its useful range

A5.2.3 Administrative controls

Embedded lasers

A5.2.3.1 Embedded lasers must be operated according to the manufacturer's instructions.

A5.2.3.2 If access to the embedded laser is uncontrolled and a key switch is provided, this must be withdrawn and stored in a safe place when the product is not in use.

N.B. Additional measures apply for maintenance and service activities (see Appendix 6).

Class 1M and 2M lasers

A5.2.3.3 The use of optical viewing aids and optical components must be strictly controlled around Class 1M and 2M lasers:

(i) magnifiers, eye loupes and concave mirrors within 100mm of the source in the case of the high divergence type lasers; and

(ii) binoculars and telescopes or similar arrangements of optical components that decrease the beam size, within the Extended Nominal Ocular Hazard Distance in the case of collimated beam type lasers.

Options include:

(i) banning the use of viewing aids in the area;

(ii) equipping viewing aids with filters that block at the laser wavelength;

(iii) fitting an interlocked shutter or turning mirror arrangement that prevents the laser beam entering the viewing aid when the laser is on.

Visible beam lasers

A5.2.3.4 Class 2, Class 2M and Class 3R visible beam lasers present an extreme dazzle hazard and must not be used in areas where working at heights and vehicle driving is taking place. More generally, visible beam lasers must not be deliberately pointed at people or into areas where other people unconnected with the laser work may be present; and the user must not stare into the beam.

A5.3 High Risk lasers

A5.3.1 General

A5.3.1.1 High Risk lasers (see definitions in Section 3) must only be operated inside Designated Laser Areas (See Appendix 7).

A5.3.1.2 Before starting work involving High Risk lasers a number of basic risk reduction measures must be considered:

- Can a lower powered laser be used?
- Can the output power of the laser be restricted if full power is not needed?
- Can intra-beam viewing be prevented by engineering design?
- Can the laser be used in a screened off area - limiting potential for others to be affected?
- Can work be carried out in a total enclosure?

A5.3.1.3 All work involving High Risk lasers must be covered by risk assessments and Standing Orders.

A5.3.1.4 The risk assessment must address, in particular, any deviations from implementing the control measures set out below.

A5.3.1.5 Laser Nominated Persons must be suitably trained in the operating techniques required and inexperienced staff must be adequately supervised.

A5.3.2 Engineering controls

Control of access

A5.3.2.1 Lasers inside a Designated Laser Area (DLA) must be linked into the external interlock chain provided within the DLA, either using the remote interlock connector on the laser or an external safety shutter, such that:

- The laser emission is rapidly terminated when a break occurs in the external interlock chain. For pulsed systems, if termination is achieved by removal of the energy source, this must be accompanied by the dumping of any residual energy which could give rise to further laser pulses;
- Resetting the external interlock chain must not cause automatic emission of hazardous levels of laser radiation. A manual operation must be required for reinstatement of the laser emission.
- If an external safety shutter on the laser it must be:
  - located either within the protective housing or, if external, as close to the laser aperture as reasonably practicable and in fixed location to it;
  - of a robust, fail-safe design and construction;
  - fast acting;
  - provided with a clear visual indication of when it is in its closed position. This indication must be derived from the location of the interlocked beam stop and not from some control signal or interruption in the external interlock chain;
  - provided with an approved means of connection to the external interlock chain.

Design of beam paths

A5.3.2.2 High Risk laser beam paths must take account of the basic open beam path design principles in A5.2.2 plus the restricted open beam path design principles:

Restricted beam path design principles

i. Main and hazardous secondary beams are enclosed

ii. Lasers and optics that define the beam path are securely mounted

iii. Beam paths are as short as reasonably practicable with a minimum number of directional changes

iv. Open beam paths are clear of surfaces producing hazardous reflections

Design of enclosures

A5.3.2.3 Beam stops and enclosures for this purpose need to be robust and firmly located in position. Screening for Class 4 lasers must be of fire resistant material and beam stops must have a heat dissipating capacity sufficient for the output of the laser. (N.B. For high average power laser beams, such as are used for materials processing, the potential of the laser beam to penetrate an otherwise opaque screen by melting or vaporising the material of construction must be considered; design details for protective elements exposed to damaging levels of laser radiation can be found in EN 60825-4 'Safety of laser products: Part 4 - Laser Guards')

A5.3.2.4 Removable sections of enclosures should be fixed so that tools are required for their removal.

A5.3.2.5 The material of construction of enclosures should be opaque at the laser wavelength(s) and gaps in the enclosure should be sealed.

A5.3.2.6 The interlocking of removable sections of an enclosure is not a general requirement. If an interlock override is required then the use of the override must activate a visual or audible warning and the act of replacing the removable sections must reset the override.

A5.3.2.7 Enclosure and removable panels must be properly labelled. (See Appendix 8)

Permitted deviations from beam path principles

A5.3.2.8 Deviations from the basic and restricted beam path design principles are only permitted after a thorough risk assessment has been made.

A5.3.2.9 Calculations of worst case exposure to laser radiation must be referenced or appended to the risk assessment. The risk assessment should also include all measures taken and a note of why engineering controls are not feasible in this case.

A5.3.2.10 Where complete beam enclosure is impractical then a combination of local enclosure (in particular around sources of scattered radiation such as laser dye cells and sources of multiple beams such as prisms and filter stacks) and peripheral enclosure (skirts around optical tables) must be employed.

A5.3.2.11 In general, deviations should only be permitted if alterative engineering controls (e.g. a pressure pad or intruder-type beam interrupt in the case of beams crossing walk-ways) are implemented.

A5.3.2.12 Administrative controls (e.g. the use of retractable tape or chain or by floor markings in the case of beams crossing walk-ways, restrictions in the use of objects with flat shiny surfaces in the case of open beam paths) may only be considered to replace engineering controls if it can be demonstrated that the maximum reasonably foreseeable laser exposure is less that 5 times the MPE for accidental exposure.

Beam release

A5.3.2.13 If the master laser control panel of the laser cannot be located less than 2m away and in line of sight from where persons could receive a hazardous exposure from the beam, then a clear system of communication must be established between the laser operator and any person in the hazard zone, giving adequate warning of each activation of the laser hazard.

A5.3.2.14 The following considerations must be made in regard to the transfer of High Risk laser beams between rooms:

- Persons in the room receiving the laser beam must have sole and overriding control to prevent the emergence of the laser hazard. The means of preventing the emergence of the laser hazard must be clearly visible from within the room and an indication must be provided on the status of the laser with regard to emission of laser radiation.
- Persons in the room containing the laser must have a reliable means of terminating the beam path within the room.

A5.3.3 Administrative controls

Unauthorised use

A5.3.3.1 If access to the laser is uncontrolled then the key must be withdrawn from the switch when the laser is not in use and stored in a safe place.

Unintended reflections

A5.3.3.2 Watches, rings and other items of jewellery that might specularly reflect a laser beam must be removed or covered.

A5.3.3.3 Other items with shiny surfaces must be kept away from open beam paths. Optical benches must be kept free from clutter (N.B. Many surfaces which appear visually dull will be highly specularly reflecting for infrared radiation).

A5.3.3.4 The individual who adjusts or introduces an optical component into a beam path is responsible for identifying and terminating each and every stray beam coming from that component.

A5.3.3.5 The placement of additional optics should be planned to minimise the possibility of stray reflections.

A5.3.4 Personal Protective Equipment

A5.3.4.1 Laser safety eyewear must be provided and worn if, after applying all reasonably practicable control measures, adequate protection for the eyes has not been achieved. In general, this applies to all people working with High Risk lasers when the beam is not totally enclosed (See Appendix 9 for details of selection and use of laser safety eyewear).

A5.3.4.2 If the High Risk laser hazard is only present occasionally then controls should be introduced (e.g. deployment of engineering means to isolate the laser hazard; initiate a pre-warning to replace eyewear) to allow the removal of laser safety eyewear in the laser area when it is safe to do so.

A5.3.4.3 The risk of skin burns must be assessed when working with Class 4 lasers and appropriate measures taken. Where reasonably practicable exposed skin should be covered. This applies particularly where there is a risk of a serious burn, or exposure to UV laser radiation.

A5.4 Diode Lasers (General)

Laser diodes can easily be mistaken for other forms of light emitting diodes and simple testing techniques can cause them to produce a light output that is harmful to the eyes. The following additional control measures apply:

5.4.1 Laser diodes not incorporated in equipment must be kept in a container labelled with classification and registration particulars, and locked way;

5.4.2 Before laser diodes are incorporated into equipment, any energy storing components therein must first be discharged;

5.4.3 Before disposal of laser diodes, the LRO must ensure that they are made non-operational.

Appendix 6. Laser control measures: additional requirements for specific High Risk laser activities

A6.1 Open Beam Work

A6.1.1 The following initial safety checks for open beam work should be considered for inclusion in the Standing Orders for work with unenclosed High Risk laser beams.

Before releasing High Risk laser beams:

- Beam paths should be inspected for any objects that should not be there and any beam line components that may have been displaced or misaligned.
- Any screens/enclosures or beam stops that have been removed should be replaced.
- All optics should be checked for damage, and the stability of optics mounts verified prior to operation of laser.
- Check that only authorized people are in the area.
- Check that everyone in the area is wearing appropriate laser safety eyewear.
- Give prior warning that the laser beam is about to be launched.

A6.1.2 Beam alignment of open beam paths is the most common cause of laser eye injuries. The following guidelines should be considered for inclusion in the Standing Orders.

- Only suitably trained and authorised Laser Nominated Persons may carry out alignment.
- Alignment should be carried out with one or at most two authorised laser operators. All other persons should be excluded from the room during this procedure.
- Watches, bracelets and other reflective jewellery should be removed.
- Appropriate laser safety eyewear to be worn.
- Initial alignment should be at the lowest possible power, preferably Class 2 or Class 1, by attenuating the laser or by use of an alignment laser.
- Analyze each and every optical element in the beam path for stray reflections and install suitable beam blocks. (The blocks must be stable, preferably locked to the table.)
- Restricted access, unauthorized personnel must be excluded from the room or area.

- Under no circumstances must direct viewing of the laser beam be attempted even if the beam has been attenuated. The use of a video camera for remote viewing should be considered.
- Alignment with a higher power beam should be carried out using laser safety eyewear. The table below gives examples of suitable techniques.

Wavelength range	**Techniques for beam position detection with the operator using laser safety eyewear**
Visible only	Introduce an attenuator to reduce accessible emission to Class 3R or below. Protective eyewear can then be removed. Alternatively wear laser alignment eyewear.
UV and/or Visible	Use fluorescent card (e.g. impregnate paper with dye, mark target with highlighter ink): fluorescence at shifted wavelength can be seen through protective eyewear. Attenuate the beam and use a CCD camera
Infrared only	Options include: ➢ liquid crystal paper, which changes colour when heated ➢ heat sensitive fax/chart recorder paper ➢ fluorescent-coated blocks illuminated with UV lamps ➢ for near infrared, phosphor or scintillation cards ➢ attenuate the beam and use a CCD camera ➢ simple detector in conjunction with an aperture (or a position sensitive centroid or quadrant detector) to locate the centre of the beam.
Single Pulse lasers	Use black coated or lithographic paper; the coating is ablated by the more powerful pulsed lasers.
Any wavelengths	Use a collinear low power visible cw laser for principal alignment. Introduce variable (iris) diaphragms to aid alignment.
'All' visible wavelengths	Multi-wavelength alignment may have to be carried out without laser safety eyewear, as it would otherwise be impossible to visualise the laser beam on a card.

A6.1.3 Where the alignment technique involves two people, the one viewing the position of the laser beam and the other blocking and unblocking the laser beam, the person viewing the beam should be provided with a fail-safe engineered means (e.g. a key control or a hand held button on a flying lead operating a simple external shutter) to prevent unintentional activation of the laser hazard.

A6.1.4 Where the alignment requires the simultaneous presence of open beam Class 3B and/or 4 laser beams at several visible wavelengths for which there is no suitable eye protection available with sufficient visible transmission, the following steps must be taken:

- Consider complete enclosure, using cameras and motorized controllers for beam alignment.
- If open beam work is inevitable, expose the minimum number of wavelengths simultaneously and use eyewear that protects against the most powerful beam(s) exposed.
- Implement strict administrative control of reflecting surfaces and use optical mounts that prevent excessive angular adjustment, especially in the vertical plane.
- All optical mounts and tools (screwdrivers etc) should have matt surfaces.
- The operator(s) when making adjustments must exercise extra caution.

A6.2 Maintenance and service of laser equipment

A6.2.1 Maintenance of laser equipment

The following precautions should be considered for inclusion in the Standing Orders.

- Before commencing the maintenance, the manual for the laser system should be consulted, to identify the recommended procedure.
- In the case of anything other than routine maintenance, and/or when the laser manual does not give a procedure, the advice of the equipment supplier should be sought. Some procedures may go beyond the competence of the laser user.
- The risks associated with the procedure should be assessed, the control measures reviewed, and the conclusions recorded. In the case of some regular maintenance procedures there may be an existing protocol that is suitable and sufficient.
- Maintenance involving the alignment of a laser beam inside a laser enclosure, for instance introducing the pump laser into a frequency mixing crystal, can lead to an increased risk of laser radiation exposure. A risk assessment for the procedure must be carried out.

A6.2.2 Service using external contractors

A6.2.2.1 Contractors must supply a method statement for approval before work can proceed. Key considerations in assessing the method statement include:

- If the alignment procedure is followed, are there any foreseeable circumstances where an accident could happen?
- Is the method of alignment clear and unambiguous?
- Does the procedure require the service engineer to remove laser safety eyewear? If so, is this justified and what safeguards are put in place to compensate? (These should be specific activities with no freedom of choice, only specific instructions).
- Are others (e.g. spectators) within the vicinity at risk?

N.B. The host organization retains a duty of care for all work on site even if waivers are given by the contractor.

A6.2.2.2 Before permitting an external laser service engineer to conduct service work on site the responsible LRO must:

- Be satisfied that the person conducting the servicing is competent.
- Establish the boundaries of the hazard area and ensure the provision of appropriate PPE (laser safety eyewear etc.) for those in the area, and the means by which other personnel will be excluded.
- Review the hazards to be exposed and the procedures to be followed during servicing activities. This review should place particular emphasis on beam control and termination (e.g. large area beam stops), beam visualisation techniques for alignment, and the transfer of control, especially where servicing takes place at a point remote from the equipment controls.
- Review emergency procedures, including how the equipment would be isolated if there is a risk of injury from electrical or mechanical hazards, or how a fire would be extinguished if there are open Class 4 laser beams. This may involve the presence of a company employee (perhaps the LRO) during the servicing, and the safety of that employee must then also be considered.
- Review isolation procedures (e.g. Lock-Out-Tag-Out (LOTO)) for times when the service engineer may wish to leave the area.
- Review the safety of the proposed service activity (i.e. are the measures proposed in the risk assessment and method statement adequate?)

A6.2.2.3 The LRO must issue a Permit to Work before work is allowed to proceed.

A6.2.2.4 The LRO must impose a system of work for handing over the equipment to a service engineer and accepting it back when the work is completed.

A6.2.2.5 After completion of the work the LRO must check:

- that the equipment has been restored to normal operation and is safe to use.
- that overrides and tools have been removed and protective covers replaced.
- that temporary warning signs have been taken down.
- That the log book for the equipment records the servicing operation, what was done and any consequent changes to the performance of the laser product.

A6.2.3 Temporary set-ups

Subject to a risk assessment evaluation the following relaxations to the control measures may be applied to laser enclosures erected for service activities. Such temporary set-ups may also be used for maintenance and trials/demonstrations involving High Risk and Embedded lasers products.

A6.2.3.1 High Risk lasers may be operated outside a DLA provided that a temporary laser hazard area is established with screens, coupled with laser warning signs and lights.

A6.2.3.2 Warning signs and lights may be used in place of interlocks to control access to the laser hazard area.

A6.3 Outdoor Laser Use

A6.3.1 Risk assessment

A6.3.1.1 A risk assessment must be made before Class 1M (collimated beam), Class 2M (collimated beam), Class 3B or Class 4 lasers are used outdoors.

A6.3.1.2 The risk assessment must include an estimate of:

- The ENOHD for the 'raw' laser beam.
- The potential of visible laser beams to dazzle or distract spectators and those working at heights or driving vehicles (e.g. motor vehicles, aircraft).
- The potential for eye or skin injury from High Risk laser beams, including specular reflections.
- The potential injury from diffuse reflections from Class 4 laser beams, including back reflections in the case of beams propagating through fog and rain.

A6.3.2 Approval

A6.3.2.1 The OLRO must be provided with the following documentation/information:

- A risk assessment.
- A statement on the purpose and duration of the outdoor work.

- A description of the means of defining and enforcing the boundaries of the hazard control area (i.e. the area within which the Class 1AEL or MPE, as appropriate, can be exceeded) for spectators and other persons present.
- The means by which the laser will be fixed in position and the beam manipulated, and any limitations placed upon the pointing of the laser beam.
- The means of protecting people within the hazard area.

A6.3.2.2 The OLRO and Director must approve the risk assessment before outdoor laser work is allowed to commence.

A6.3.2.3 For laser displays and shows guidance can be found in IEC 60825 Part 3 and the Health and Safety Executive Guidance Note HS(G)95. If applicable the requirements of HS(G)95 must be complied with and any statutory notifications must be made.

6.4 Working with optical fibre systems

Guidance on fibre optic laser work can be found in IEC 60825 Part 2.'Safety of optical fibre communication systems' though the standard strictly only applies to extended Class 1 communications systems.

Optical fibres carrying laser radiation normally provide a complete enclosure of the radiation, and so prevent access to it. However, if a fibre is disconnected or a fibre break occurs, hazardous levels of laser exposure can be present. IEC 60825 Part 2 introduces the concept of Hazard Levels, corresponding exactly to the classification scheme for lasers. This scheme is particularly useful for dealing with servicing of extended optical communication systems that may be driven by Class 3B or 4 lasers but are essentially closed Class 1 systems in normal operation.

Good practice (all lasers)

A6.4.1 Do not stare with unprotected eyes or with any unapproved collimating device at the fibre ends or connector faces.

A6.4.2 Fibre end(s) must be individually or collectively covered when not being used.

A6.4.3 Do not cleave ribbon fibres as an unseparated ribbon, or use ribbon splicers, without first assessing the hazard of exposure to multiple laser outputs.

A6.4.4 When using optical test cords, connect the optical power source last and disconnect it first.

A6.4.5 Dispose of fibre off-cuts (sharps) in an approved container.

High Risk lasers

A6.4.6 Before connecting High Risk laser test equipment assess the potential hazard at other points of access to the optical fibre system and either block the open ends or take appropriate action to prevent access.

A6.4.7 Optical fibre in mixed service conduits must be protected and clearly distinguished from electrical and other service cabling.

Appendix 7. Laser control measures: Designated Laser Areas

A7.1 Containment of the laser hazard

A7.1.1 The Designated Laser area (DLA) must present a robust physical boundary capable of adequately containing the laser radiation generated within it, thereby protecting those outside the boundary from hazardous exposure to laser radiation.

A7.1.2 All parts of the DLA boundary that could be exposed to laser radiation and that are not opaque at the laser wavelength(s), including windows, must be screened during laser use.

A7.1.3 Warning signs must be displayed at each and every point of entry to the DLA as described in Appendix 8.

A7.1.4 Clearly visible lights must be installed at each and every point of entry;

(i) amber 'laser energised' lights and/or

(ii) red 'laser ON' lights.

If 'laser energised' lights are used, they must be illuminated whenever a High Risk laser within the DLA is energised, if and only if it has the potential to emit laser radiation (e.g. for commercial laser products, when the laser is powered up and the key switch activated). If this facility is not provided on the laser then some other reliable means (e.g. the status of a safety shutter mounted over the laser aperture) must be used.

If 'laser ON' lights are used, they must operate at least 5 seconds before High Risk laser radiation is accessible to a person entering the DLA.

Additional green 'safe to enter' lights may also be installed at entrances to laser areas and the lights can be replaced by a clearly visible monitor screen providing that the same colour scheme is adopted (see A8.5.2) and that the screen offers sufficient visual impact over a wide range of angles.

A7.1.5 If practicable the laser laboratory should have a high level of illumination.

A7.1.6 Windows should be kept to a minimum and may need to be covered or protected. Preferably, the covering should be a rigid fixed panel.

A7.1.7 Walls, ceilings and fittings should be painted with a light coloured matt paint to enhance illumination and minimise specular reflections. Reflecting surfaces such as the use of glass-fronted cupboards should be avoided.

A7.2 Access

A7.2.1 Lasers inside a Designated Laser Area (DLA) must be linked into the external interlock chain provided within the DLA, either using the remote interlock connector on the laser or an external safety shutter (see A5.3.2.1).

A7.2.2 Interlock overrides at access doors are only permitted under the following circumstances:

- Overrides that can be operated only from within the DLA must be located near the door. Controls must be installed to prevent the escape of hazardous levels of laser radiation when the door is opened.
- Overrides that can be operated from outside the DLA must be of a coded or key operated type with access restricted to authorised personnel. Secondary screening (e.g. labyrinth) within the DLA must ensure that the laser hazard zone does not extend outside the door when it is opened. Exceptionally, where space does not permit a labyrinth entrance, then during activities (e.g. beam alignment) when a beam could emerge through the open door:
  - (i) a warning light should be placed above the door to indicate the laser hazard status;
  - (ii) a prominent temporary warning sign should be placed near or on the outside of the door during alignment;
  - (iii) the door should be locked but with a key for emergency access (e.g. a knob to lock the door on the inside and a key behind a break glass cover on the outside).

A7.3 Layout

A7.3.1 Lasers should point away from and not towards the DLA entrance.

A7.3.2 If several High Risk lasers and/or laser wavelengths are simultaneously and independently accessible within the DLA:

- the different laser hazard areas should be separated (e.g. by the use of enclosures and partitioning) and access to these areas placed under local control (e.g. by use of an intruder alarm or barrier connected to the external interlock of the laser);
- The risk assessment and Standing Orders must also address procedures for restricting the simultaneous operation of more than one laser and provision of the correct laser safety eyewear within a single partitioned area e.g. by control of the laser keys;

See also Appendix 9 for information on additional marking of laser safety eyewear to avoid wrong selection.

A7.3.3 If different laser control measures and/or laser safety eyewear are employed in different partitioned areas within a DLA, the Standing Orders must provide procedures for persons wishing to move between the different areas.

A7.3.4 SHE Group must be consulted about the provision of suitable fire fighting equipment and adequate means of escape from the DLA.

A7.3.5 Any areas within the DLA in which non-laser (or Low Risk laser) activities take place, such as computer work, clean rooms or sample preparation rooms, must be partitioned off from those involving High Risk lasers so that laser safety eyewear is not required. The use of chairs in a DLA, if essential, must be restricted to screened off areas.

A7.3.6 Where areas are designated laser hazard-free, a laser hazard warning (e.g. 'laser energised' amber lights) should be installed at points of exit into laser hazard areas. Alternatives includes:

(i) instigating a search procedure before activating the laser hazard that includes a search of hazard free areas;

(ii) arranging for an audible alarm to sound in the lab if the laser hazard is activated from within the lab.

A7.4 Administrative controls

A7.4.1 Standing Orders must be readily available within the DLA.

Visitors

A7.4.2 A combination of engineering controls (e.g. local beam enclosure, barriers to restrict visitors to a region not closer than an arms length and/or the NOHD away from accessible beam components), administrative control (e.g. supervision, explanation of restrictions) and eye protection (e.g. provision of safety eyewear, fixed screens to view through) must be considered to safeguard visitors.

A7.4.3 A maximum numbers of visitors should be established and consideration given to the need for additional persons to be present to help supervise the visitors.

Appendix 8. Labels and signs

A8.1 Laser Product Labelling

All lasers used within STFC must be labelled in accordance with the requirements of EN 60825-1:2007. The placing of laser product labels is primarily the responsibility of the manufacturer or supplier. Such labels have black text and border on a yellow background.

All laser products other than Class 1 (intrinsic) require a Class label; and with the exception of Class 1 (intrinsic) and Class 1 (embedded) they require a starburst warning triangle and an information label (e.g. wavelength(s) and maximum output power). They also require an explanatory label, the wording of which depends on Class.

The table below provides the wording of the explanatory label for this Code.

Class	Explanatory label
1	none
1M div	LASER RADIATION*. DO NOT VIEW DIRECTLY WITH MAGNIFIERS
1M coll	LASER RADIATION*. DO NOT VIEW DIRECTLY WITH BINOCULARS OR TELESCOPES
2	LASER RADIATION*. DO NOT STARE INTO THE BEAM
2M div	LASER RADIATION*. DO NOT STARE INTO THE BEAM OR VIEW DIRECTLY WITH MAGNIFIERS
2M coll	LASER RADIATION*. DO NOT STARE INTO THE BEAM OR VIEW DIRECTLY WITH BINOCULARS OR TELESCOPES
3R	LASER RADIATION*. AVOID DIRECT EYE EXPOSURE
3B	LASER RADIATION*. AVOID DIRECT EYE EXPOSURE
4	LASER RADIATION*. AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION

*For output wavelengths outside the visible wavelength range (400 – 700 nm) the word ‘radiation’ must be replaced by ‘invisible radiation’ or ‘visible and invisible radiation’.

Reclassification of laser products

A8.1.1 Where lasers arrive on site that are not properly labelled according to EN 60825-1 then in the first instance, the supplier of the laser should be requested to update the labelling under the terms of the purchase contract.

A8.1.2 The re-labelling of commercial laser products classified according to the old EN60825 classification scheme or to the current US scheme in all cases requires the approval of the OLRO. The result must be documented and if possible the manufacturer of the laser should be asked to confirm the newly assigned Class.

A8.1.3 Where a laser product is manufactured and/or assembled within the STFC, or is modified significantly, it must be reclassified (or its classification confirmed) with the approval of the OLRO and labelled accordingly. This requirement for formal reclassification also applies to the situation when enclosures are added to a laser and its output so as to totally isolate the

laser hazard i.e. it must nevertheless not be labelled as a Class 1 (Embedded laser) product.

A8.2 Enclosures

See A5.3.2.3 for design requirements of enclosures.

A8.2.1 If the laser radiation in an area is enclosed so that the control measures in the vicinity of the enclosure are pertaining to a lower Class of laser than the sources in operation (e.g. in the extreme case, an area with fully enclosed lasers and optics where there is no PPE requirement in the area for most activities), then each part of the enclosure designed to be removed for normal use or for maintenance must be labelled using the EN 60825-1 format i.e. the labels must comprise the following, all black on a yellow background:

CAUTION – CLASS XX LASER RADIATION WHEN OPEN

<<Explanatory label wording for Class of enclosed laser>> (see A8.1)

for example

This requirement also applies to the ports of target chambers, where though they may not contain a laser source nevertheless can present a laser hazard.

A8.2.2 Each panel of an enclosure designed to be removed that is safety interlocked must be labelled using the EN 60825-1 format for an interlocked panel i.e. the labels must comprise the following, all black on a yellow background:

CAUTION – CLASS XX LASER RADIATION WHEN OPEN AND INTERLOCKS DEFEATED

<<Explanatory label wording for Class of enclosed laser>> (see A8.1)

A8.2.3 A beam stop (a block, shutter etc) that terminates a laser beam may be considered as a removable enclosure and labelled as for a removable panel.

A8.3 Laser apertures

A8.3.1 Any opening in an enclosure through which a Class 3R, 3B or 4 laser beam is intended to pass must have a laser aperture label affixed close to it, on the side from which the beam emerges, providing the aperture on this side is visible to laser users. The black on yellow labelling must bear the words:

Examples include safety shutters in DLA walls that allow entry of laser radiation from the adjacent room and the output of an enclosure containing a mixing crystal but no laser.

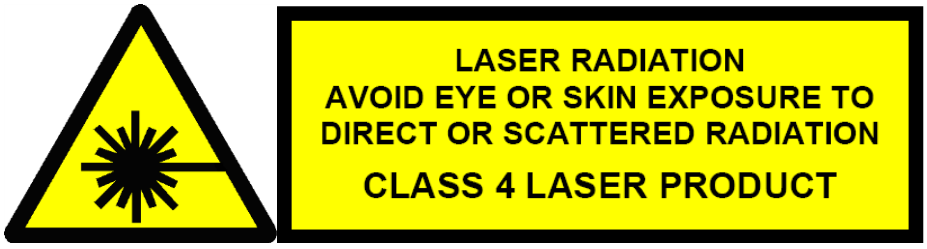
A8.4 Reproduction of labels

A8.4.1 Explanatory labels (as set out in the table in A8.1) should be reproduced at laser apertures separated by more than 2m. This also applies in the case of fibre delivered beams where the fibre length is more than 2m (e.g. a tag should be fitted near the fibre end with the appropriate wording.)

A8.5 Entrance to DLA

A8.5.1 The following information should be displayed at all points of entry to a DLA where High Risk lasers are in operation:

- The wording on the basic explanatory information given in the table in A8.1 above combined with the laser hazard warning triangle (black star-burst on yellow background). The word “CAUTION” or “DANGER” can be added, if appropriate;



- For a DLA to which entry is restricted, an authoritative statement such as “no entry when warning lights are on” combined with the prohibited entry sign (person icon plus diagonal red line and circle on a white background) complying with the Health and Safety (Safety Signs and Signals) Regulations;

- Where there are mandatory requirements on persons entering the DLA, an authoritative statement combined with the mandatory action sign (e.g. “laser protective eyewear must be worn on entry when warning lights are on” with a sign comprising a white outline face with goggles in a white circle on a blue background) complying with the Health and Safety (Safety Signs and Signals) Regulations.

- Clearly visible lights or a monitor screen must indicate when High Risk lasers are energized (i.e. have the capability to emit), see 7.1.4.

A8.5.2 The general warning light colour scheme must follow the following scheme:

Laser warning lights

GREEN = safe to enter

AMBER = restricted access. Read warning signs before entering. Eyewear required.

= same as RED (if no amber lights installed)

RED (in addition to amber)
= restricted access. Read warning signs before entering (additional access restrictions). Eyewear required.

A8.5.3 Laser areas containing only Low Risk lasers but excluding Class 1 and Embedded laser products, require only the wording on the basic explanatory information given in the table in A8.1 above combined with the laser hazard warning triangle (black star-burst on yellow background).

for example

A8.6 Temporary warning signs

A8.6.1 In cases where changes in the laser hazard in an area are infrequent (e.g. servicing of a laser in-situ) then a temporary warning sign can be regarded as an effective means of controlling entry. Such a sign must be affixed at points of entry to the area. (see 'Temporary set-ups' in A6.2.3).

A8.6.2 Temporary signs must be sufficiently large and bold to attract attention, using the international standard symbols for prohibited entry etc, depending on the consequences of entry. Such signs can be used only for a maximum of 48 hours, otherwise the approval of the OLRO must be obtained.

Appendix 9. Selection and use of laser safety eyewear

Laser protective eyewear is not a substitute for other precautions; indeed, it is only to be used if, after applying all reasonably practicable control measures, adequate protection for the eyes has not been achieved.

Laser Protective Eyewear is available from a number of laser component suppliers and can be expensive. However, it is generally a key item of safety and economies should not be made in this area; uncomfortable eyewear with a restricted field of view is unsuitable for the regular laser user.

Laser safety eyewear is marked to show the wavelength(s) for which it provides protection and the level of protection. Laser protective eyewear is given a scale number with a prefix 'L'. Adjustment eyewear is also available for visible cw laser radiation in which the filters attenuate the laser radiation to a safe level for 0.25 s exposure. In this way, visible laser beams can safely be viewed during adjustment work. The scale number for adjustment eyewear is given the prefix 'R'.

A9.1 Mandatory requirements

The eyewear must be:

- CE marked;
- marked as providing the necessary level of protection for the assessed maximum exposure at the appropriate wavelength(s);
- held in appropriate receptacles providing clear type identification, protection from dust and scratching and separated according to type of eyewear if more than one specification is available; located near the entrance to the Designated Laser Area;
- Inspected regularly and replaced or repaired if: the filters are excessively marked or damaged or display an anomalous colouration; the mechanical integrity of the frames is suspect; or elastic tape is used and has become worn.

A9.2 Selection of protective eyewear

When choosing appropriate eyewear each of the following must be considered:

- the wavelength of operation.
- the reasonably foreseeable worst-case effective exposure (beam power or pulse energy, and beam diameter).
- visible light transmission, and the ability to see warning lights or other indicators through the filters;
- general design, comfort, ventilation, peripheral vision, and provision for spectacle correction (either by using goggle-style protectors which fit over normal spectacles, or protective spectacles which incorporate the wearer's own optical correction);

- use of the eyewear, whether for occasional casual use or for working for long periods, perhaps in restricted spaces where the eyewear may be knocked.

A9.3 Identifying the correct eyewear

Where several types of laser safety eyewear are available for different lasers in the DLA, effective action must be taken to reduce the likelihood of incorrect selection of eyewear occurring. This could include:

- paint a distinctive mark on the eyewear, using a colour code to readily identify the eyewear;
- make it part of the procedures for the LRO to ensure that only the eyewear appropriate to the laser(s) in use is available in the area.
- inappropriate eyewear for the work in laser progress is locked away.

A9.4 Hygiene

If the eyewear is to be worn by more than one person, then an antiseptic spray and/or medical wipes, lens cleaner and tissues should be provided in the vicinity of where the eyewear is stored. In addition, the use of anti-fogging sprays and basic lens cleaning fluids should be considered.

Appendix 10. Medical inspections, accident and incident reporting

A10.1 Incident reporting

Significant occurrences in the eyes possibly relating to laser damage include: pain or discomfort, blurring of vision, loss of ability to read small print, or any unusual appearance or sensation, such as persistent ‘after-images’ following exposure to high intensity light in the visible range.

A10.1.1 Any person suspecting a laser injury of any kind must immediately seek medical examination by a suitably qualified ophthalmologist as soon as possible and within 24 hours, and notify management as per local procedures (see SHE Safety Code 5 Incident Reporting and Investigation). The procedure for accidents must be included in the Standing Orders for the laser activity.

A10.1.2 In the event of a failure of a protective measure that could have led to an incident, laser emission must be terminated until a full assessment of the failure has been made and corrective action taken. The incident must be reported to the LRO and management notified as per local procedures (see SHE Safety Code 5 Incident Reporting and Investigation).

A10.1.3 In the unlikely event of an eye injury caused by an individual staring down the beam of a lower powered laser the emergency arrangements for High Risk lasers must be followed (A10.1.1).

A10.2 Return to work

A10.2.1 Anyone returning from absence due to injury or disease of the eyes must notify the site medical centre before resuming work with lasers.

Appendix 11. Risk assessment for laser use

The requirements for conducting and documenting risk assessments are described in STFC Safety Code 6 Risk Management. The recommended form to use for laser risk assessments is the STFC Quantitative Risk Assessment Form. Contractors may use their own format for risk assessments but they must meet the standards laid out in this code.

A risk assessment is required for all High Risk laser work, and for use of Low Risk category lasers on those exceptional occasions where the requirements of this Code as set out in Appendix 5 cannot be met.

The laser radiation hazard is unique: with its long range, the ease with which the hazard path can be redirected, its speed of impact and immediacy of injury and the severity of the injury to the eyes. Also unique is the wide range of control measures available to deal with the risk and the need to strike a balance between the restrictions of engineering controls with the flexibility of administrative controls.

Ideally, the risk assessment will specify the 'who and how' of potentially injurious situations, estimate of risk associated with each such situation and show how this leads to the choice of control measures, reflecting the preference of engineering and administrative controls over the use of safety eyewear. The standing orders will link in with the risk assessment i.e. where an engineering control is specified the SOs will specify a maintenance procedure for the control, where an administrative control is specified it will be also be present in the SOs and where eyewear is specified in the risk assessment then the SOs will include procedures for selection, storage and maintenance.

Following the recommendations in TR 60825-14: 2004 'A user's guide' this Code requires that the risk assessment determine the protective control measures necessary to ensure safe operation. In order to do this it is recommended that these control measures be disregarded in the initial listing of potentially injurious situations (see below), the first step of the assessment. By so doing, the control measures can be listed in step 2 and in step 3 these controls can (if appropriate) be marked as sufficient.

A11.1 Risk assessment to establish or confirm control measures

A11.1.1. Step 1: What are the hazards?

A11.1.1.1 The risk assessment should list potentially injurious situations, disregarding those existing control measures. Hazards must include both beam and associated non-beam hazards; potential injurious situations must include but not necessarily be limited to:

- Normal operation (e.g. running the laser without major beam adjustment).
- Maintenance operations (including routine beam alignment).
- Service operations (e.g. major disruption and realignment).
- Emergency operations.
- Visitors present.
- External laser service engineers present.

A11.1.2. Step 2: Who might be harmed and how?

A11.1.2.1 Persons to consider in the context of each potentially injurious situation identified must include:

- Laser workers in the room and actively involved in the specific laser work under consideration (e.g. staff, contractors).
- Others in the room but not actively involved in the specific laser work under consideration (e.g. other activities in the room, visitors).
- Persons who could enter the laser area during laser operation *without terminating* the laser hazard (e.g. approved persons via interlock override; any person with a reason to enter if laser is not interlocked to the door).
- Persons outside the laser room who are at risk (e.g. when the room door is opened during laser activity) from laser radiation through a window or hole in the perimeter.

A11.1.2.2 The injuries to be considered must include eye or skin burns as a result of exposure to main or errant laser beam.

A11.1.3 Step 2: What are you already doing?

A11.1.3.1 For each potentially injurious situation with the assessed risk other than 'low' a list must be made of Engineering and administrative controls and the use of PPE, now including any controls previously disregarded as described in A11.1.1.1.

A11.1.4 Next Steps:

Then follow the STFC Code

When considering control measures in place or additional measures that could be put in place the 'best practice' as set out in Appendices 5 & 6 should be considered and where rejected the reasons why should be noted in the Risk Assessment.

Appendix 12. Laser safety documentation

The following table summarises laser safety documentation that may be required for different classes of laser:

Class	1M & 2M (div)	1M & 2M (coll)	2 & 3R	3B & 4	Embedded
Risk Assessment				√	√
Standing Orders				√	√
Laser registration form		√		√	√
Equipment maintenance and service documents					√
Permit to Work on laser equipment				√	√
Letter of appointment of OLRO, LRO, LNP etc	√	√	√	√	√
Training records	√	√	√	√	√

A12.1 Risk Assessments

Risk Assessment documentation is required for all Class 3B, Class 4 and Embedded laser products. Details are provided in Appendix 11.

A12.2 Standing Orders

12.2.1 Standing Orders are required for all Class 3B, Class 4 and Embedded laser products. The Orders must include the following information:

- A signature and date of issue.
- A brief description of the area and/or equipment to which they apply.
- An laser-centric overview of the area, highlighting any important instructions (e.g. ‘the use of personal protective equipment during normal operation is always required’):
- The type, approximate power, wavelength and classification of lasers involved.
- Identification of laser hazard area(s).
- Basic engineering and administrative controls.
- Need and form of PPE.
- Non-beam hazards.
- Contact details of the LRO and deputies.
- A table of beam and non-beam hazards, listing the source of the hazard and reference to any relevant SHE safety codes.

- Emergency procedures, identifying isolation valves and switches, E-stops, etc., procedure for summoning assistance (with names and numbers), making safe prior to evacuation of the building.
- Laser accident procedures, identifying the most appropriate Accident and Emergency Department which deals with eye injuries.
- Procedures for normal operations. Include checks of engineering controls, the use of PPE and, together with general descriptions of what is involved in normal operation, a note of any departures from the guidance in this Code, any restrictions in the use of lasers and any operations that do not conform to the manufacturer's requirements or guidance, or that are otherwise non-standard. Normal shut-down procedure should be described. See Appendices 5 and 6.
- Procedures for alignment. Procedures for alignment should be covered; see Appendix 6.
- Procedures for other maintenance and service activities. Requirements for safety checks (interlocks etc.) should be included under 'maintenance'. Servicing procedures should address the establishment of temporary hazard areas and use of external service engineers; see Appendix 6.

12.2.2 Standing Orders must link with the risk assessment i.e. where an administrative control is specified in the RA it should appear in the Standing Orders and *visa versa*.

A12.3 Registration form

All Class 1M & 2M (collimated), Embedded, 3B and Class 4 devices should be identified and a laser inventory maintained. There may be occasions when this is not practicable because the laser products are in fact just electrical components. In circumstances like this it should be the use of particular types of laser device that should be recorded. It may be useful to also note the use of Class IM & 2M (divergent), Class 3R and Class 2 products but it is not necessary to record the use of low powered Class 1 devices, Class 2 laser pointers or the use of embedded lasers in products such as DVD players and laser printers.

The registration document must include the following information:

A12.3.1. The identification of the laser product e.g. the name of the makers of the equipment, serial or asset numbers. Where appropriate, the name can be used to refer to a facility comprising several integrated laser units;

A12.3.2. The location of the laser product (e.g. building and room number).

A12.3.3. The type of laser equipment (e.g. Q-switched diode pumped Nd:YAG).

A12.3.4. The laser output (e.g. wavelength(s) plus maximum average and peak power, pulse energy and duration).

A12.3.5. The assigned class of the laser equipment (for Embedded laser equipment, note 'embedded' under 'type of laser equipment' and list the embedded laser characteristics under 'laser output'.

A12.3.6. A note of any engineering features appropriate to the class of the laser product that have been removed, overridden or otherwise not used.

A12.3.7. A note of any limitations imposed in the use of the product.

A12.3.8. The person named as responsible for the laser.

A12.4 DLA test and maintenance report

A test and maintenance report should be maintained identifying all the safety interlocks and guards and any other engineering safety controls for the DLA, indicating that they have been tested and actions taken. These should be dated and signed and a note made of the due date for the next test.

A12.5 Equipment maintenance and service reports

For equipment that needs to be kept properly serviced and maintained for safety reasons, separate maintenance and service records need to be kept. The maintenance record should follow the recommendations of the user manual and should simply note the date that maintenance was carried out, what was done, any actions taken and by whom, together with the due date for the next test. The external service engineer should complete the service record provided by the manufacturer after each visit.

A12.6 Permit to Work

The Permit to Work must address all hazards including laser radiation. With regard to the assessment the laser radiation hazard must include consideration of the following:

a. The use of screens, coupled with laser warning signs and lights to define a temporary laser hazard area;

b. Control of access to the laser hazard area;

c. The introduction of a system of work for handing over the equipment (if applicable) and accepting it back when the work is completed;

d. (For service activities) a check to ensure that tools have been removed, interlocks returned to normal operation and covers replaced.

A12.7 Letters of appointment to laser safety positions

A12.7.1 Persons appointed under the terms of this Code must be competent to carry out the duties assigned to them. This means that, with respect to these duties, they must be judged to have sufficient:

- Appreciation of the way in which laser radiation propagates in free space, the effect of optical components on this propagation, and the manner in which laser radiation can be reflected, refracted, scattered, transmitted and/or absorbed;
- Experience of work in connection with lasers;
- Training in the relevant operating procedures;

- Awareness of the hazards to the eyes and skin that may arise during use, and
- Knowledge of this Code and experience in the use of appropriate hazard control procedures and in the use of personal protective equipment.

Formal or on-the-job training prior to appointment may be necessary, but is not a prerequisite for persons with adequate experience.

A12.7.2 Letters of appointment must clearly define the scope of duties and must be dated. The recipient must be requested to acknowledge their acceptance clearly in writing.

A12.8 Training records

The requirements for this documentation are specified in SHE Safety Code 10 Provision of Safety, Health and Environmental (SHE) Training.

Appendix 13. Laser Safety Checklist

The checklist below was developed for use by the LRO to help identify shortcomings in laser safety and areas of deviation from this Code that need to be addressed in the risk assessment. It can also be used by the OLRO during routine inspections of laser areas. However, it does NOT claim to be comprehensive, nor is it designed as a check list for compliance to the Code.

Name: ..... Dept. & Section: .....

Building and Room No:..... Ext. No: .....

Building and room(s) to which this assessment applies: .....

1. Do all the laser sources have the appropriate classification and warning label(s)?

   Points to consider: **YES/NO**

   Laser products need to bear signs conforming to BS EN 60825-1.
   If commercial laser products have been modified their classification should be checked.

2. Is the use of optical viewing permitted within the laser area? **YES/NO**

   If YES, please summarise the precautions taken to preventing hazardous levels of laser exposure.
   State if Class 1M and 2M lasers are in use.

3. Are dazzle-susceptible activities (e.g. vehicle driving, working at heights) permitted within in the laser area? **YES/NO**

   If YES, please summarise the precautions taken to control these activities and/or visible laser beams
   (If no visible-beam lasers, state 'None')

4. Are there normally Class 3B and Class 4 open beam paths in the laser area? **YES/NO**

   If YES, please indicate which of the following control measures below are in place:

   a. All beam paths are enclosed as much as is reasonably practicable. YES/NO/N.A.
   b. All beam path components that generate errant beams are locally enclosed. YES/NO/N.A.
   c. All beam paths are properly terminated. YES/NO/N.A.
   d. All unprotected open horizontal laser beams lie above or below normal eye level. YES/NO/N.A.
   e. All lasers and optical components on the beam line are securely mounted. YES/NO/N.A.
   f. Shiny surfaces (including jewellery) are not permitted around laser beam paths. YES/NO/N.A.

g. Laser beam paths do not cross walkways. YES/NO/N.A.

h. All upwardly directed beams are shielded to prevent human exposure. YES/NO/N.A.

i. Laser sources and beam paths are kept under the control of competent persons YES/NO/N.A.

j. Information of the current laser hazard is clearly displayed at each and every point of access to the laser area. YES/NO/N.A.

k. Low level lighting is provided for 'lights-out' operations YES/NO/N.A.

l. Persons at risk of exposure to the laser radiation have received adequate laser safety training and instruction. YES/NO/N.A.

m. A safe method of beam alignment is provided. YES/NO/N.A.

n. A visible or audible warning of the potential laser hazard is provided. YES/NO/N.A.

o. Unauthorised persons are prevented from gaining access to the laser area. YES/NO/N.A.

p. Precautions are in place to safeguard visitors entering the laser area. YES/NO/N.A.

q. Multiple wavelengths.

r. Laser safety eyewear is provided. YES/NO/N.A.

If NO to any of the above, please summarise precautions that are taken to control these activities:

5 Do all 3B and 4 laser operations take place within a Designated Laser Area?

YES/NO

If YES, please indicate which of the following control measures below are in place:

a. The DLA presents a robust physical boundary that isolates laser radiation from personnel outside the area. YES/NO/N.A.

b. The DLA boundary (including windows) is opaque at the laser wavelengths and without gaps. YES/NO/N.A.

c. Points of entry from hazard-free to laser hazard areas within the DLA (e.g. a door or opening from a room for changing or data collection) carry current laser hazard information. YES/NO/N.A.

d. All hazards are clearly identified at all access points to the DLA. YES/NO/N.A.

e. Where different laser wavelengths are accessible in the DLA at different times accurate status information is displayed at all access points. YES/NO/N.A.

f. The laser hazard cannot extend beyond the DLA if a door into the DLA is opened. YES/NO/N.A.

g. The laser hazard is automatically terminated if an unauthorised person enters the DLA. YES/NO/N.A.

h. The laser hazards from separate laser experiments within the DLA are isolated and information of the current laser hazard within a sub-divided area is clearly displayed at points of access. YES/NO/N.A.

i. Independent non-laser activities are prohibited within the DLA. YES/NO/N.A.

j. Prior warning is provided if laser hazards are introduced from outside the DLA. YES/NO/N.A.

k. Laser beams entering the DLA from other (adjacent) areas are under sole and overriding control from within the DLA. YES/NO/N.A.

l. Temporary restrictions are imposed for servicing and other non-routine activities within the DLA YES/NO/N.A.

If NO to any of the above, please summarise precautions taken to control these activities:

6 Is laser safety eyewear provided? **YES/NO**

If YES, please which of the following control measures below are in place:

a. Laser safety eyewear provides sufficient protection for each accessible hazardous laser wavelength (including wavelengths that could be generated by non-linear effects) YES/NO/N.A.

b. Laser eyewear is properly stored and maintained in good condition. YES/NO/N.A.

c. The eyewear clearly identifies the laser/area within the DLA it is suitable for. YES/NO/N.A.

d. Lighting levels are appropriate for the visual transmission of the eyewear. YES/NO/N.A.

e. The colours of warning signs and lights are effective when viewed through the eyewear. YES/NO/N.A.

If NO to any of the above, please provide a brief justification:

7 Are there non-beam hazards associated with laser use (including during servicing and maintenance)? **YES/NO**

If YES, are control measures in place to address the following hazards:

a. Fire hazard (with Class 4 laser beams). YES/NO/N.A.

b. Laser generated fume hazard. YES/NO/N.A.

c. Electrical hazards. YES/NO/N.A.

d. Explosion hazard. YES/NO/N.A.

e. Secondary and collateral radiation. YES/NO/N.A.

f. High-pressure gas hazard. YES/NO/N.A.

g. Trip hazards and sharp corners at head height. YES/NO/N.A.

h. Other non-beam hazards:. YES/NO/N.A.

Appendix 14. Definitions of technical laser terms

A14.1 Accessible Emission Limit (AEL)
The radiation level produced in regions accessible to the user, which must not be exceeded for a given class of laser. It is generally expressed as the total power or pulse energy output of the laser.

A14.2 Beam divergence
The measure of increasing beam diameter, expressed as a linear angle, with distance of propagation. For beams with non-circular symmetry, beam divergence values in orthogonal planes may be specified.

A14.3 Class 1 Laser products
Laser products that are normally safe under reasonably foreseeable conditions or use, either because the output of the laser source is sufficiently low, or by virtue of their engineering design e.g. total enclosure of the laser output.

A14.4 Class 1M laser products
Laser products that exceed the permitted accessible emission limits for Class 1 but which are safe for viewing with the unaided eye. This situation can arise under one of two conditions:
Class 1M (high divergence beam)
The output laser beam has a high divergence; unaided viewing is safe at normal distances of accommodation but harmful levels of exposure can occur under close viewing with an eye loupe or magnifier.
Class 1M (collimated beam)
The output laser beam is reasonably collimated and has a large diameter, such that harmful exposure can occur under distant viewing with a telescope or binoculars.

A14.5 Class 2 laser products
Laser products emitting low levels of visible radiation (i.e. in the wavelength range 0.4 to 0.7 μm) that are safe by virtue of the natural aversion response to bright light.

A14.6 Class 2M laser products
Laser products emitting levels of visible radiation (i.e. in the wavelength range 0.4 to 0.7 μm) that exceed the permitted accessible emission limits for Class 2 but which are safe for viewing with the unaided eye by virtue of the natural aversion response to bright light. This situation can arise under one of two conditions:

Class 2M (high divergence beam)
The output laser beam has a high divergence; unaided viewing is safe at normal distances of accommodation but harmful levels of exposure can occur under close viewing with an eye loupe or magnifier.

Class 2M (collimated beam)
The output laser beam is reasonably collimated and has a large diameter, such that harmful exposure can occur under distant viewing with a telescope or binoculars.

A14.7 Class 3B laser products
Medium power laser products for which direct ocular exposure is unsafe, but under certain conditions they may be safely viewed via a diffuse reflector. In general these safe conditions are:
i) a minimum viewing distance of 130 mm and
ii) a maximum viewing time of 10 seconds
These lasers may present a skin hazard.

A14.8 Class 3R laser products
Laser products for which intra-beam viewing is potentially hazardous but the risk is low. For visible radiation (i.e. in the wavelength range 0.4 to 0.7 μm) the level of accessible emission can exceed the AEL for Class 2 by up to five times; for other wavelengths the level of accessible emission can exceed the AEL for Class 1 by up to five times.

A14.9 Class 4 laser products
High-power laser products. In addition to the hazard from intra-beam viewing or specular reflections, they are capable of producing hazardous diffuse reflections, may cause skin injuries and could also present a fire hazard. Their use requires extreme caution.

A14.10 Continuous Wave (CW)
The description used for a laser which produces a constant, as opposed to a pulsed laser output.

A14.11 Designated Laser Area (DLA)
A room or other enclosed working area designed to contain lasers, such that there is no laser radiation hazard beyond the defined boundary of the area.

A14.12 Diffuse reflection
The scattering of laser radiation from a rough surface.

A14.13 Extended Nominal Ocular Hazard Distance (ENOHD)
The shortest distance (generally measured from the position of the laser source) at and beyond which a laser beam is safe for aided viewing.

A14.14 Hazard level
The classification of fibre optic output at locations where interruption of the fibre might reasonably be foreseen, as described in BS EN 60825-2 ‘Safety of laser products: Part 2- Safety of optical fibre communication systems’. Hazard levels use the same nomenclature and warnings as is used for laser classes.

A14.15 Human access
Capability for part of the human body to meet hazardous laser radiation.

A14.16 Intrinsically safe
Safe by virtue of its intrinsically low emission of laser radiation. This contrasts with the emission from a Class 1 Embedded Laser Product which is safe by engineering design.

A14.17 Intra-beam viewing
The exposure of the eye to all or part of a laser beam, either directly or after specular reflection.

A14.18 Irradiance
The radiant power incident on an element of a surface divided by the area of that element (Wcm^{-2}). For normal incidence irradiation, this term is equal to the beam intensity at the surface.

A14.19 Laser
(As defined in EN 60825-1) a device that can be made to produce or amplify electromagnetic radiation in the wavelength range from 180 nm to 1 mm primarily by the process of stimulated emission. MPE values do not exist for wavelengths outside this.

A14.20 Laser Hazard Zone
The region around the laser and laser beam path within which, under all reasonably foreseeable conditions, a hazardous level of laser radiation may be present.

A14.21 Laser product
Any product or assembly of components that constitutes, incorporates or is intended to incorporate a laser or laser system.

A14.22 Laser system
A laser in combination with an appropriate laser energy source with or without additional incorporated components.

A14.23 Maximum Permissible Exposure (MPE)
That level of laser radiation to which, in normal circumstances, persons may be exposed without suffering adverse effects. MPE values for eyes and skin exposures represent the maximum levels to which the eye or skin can be exposed without consequential injury. They vary with the wavelength of the radiation, the pulse duration or exposure time, the tissue at risk and, for visible and near-infrared radiation, the size of retinal image.

A14.24 Maintenance
Adjustments or procedures specified in the user information provided by the manufacturer/supplier with the laser product, which are performed by the user for the purposes of assuring the intended performance of the product. It may require access within the laser enclosure and may expose the laser worker to additional hazards.

A14.25 Nominal Ocular Hazard Distance (NOHD)
The shortest distance (generally measured from the position of the laser source) at and beyond which a laser beam is safe for unaided viewing.

A14.26 Personal Protective Equipment (PPE)
Protection that is worn or carried. This includes laser safety eyewear and protective clothing, such as gloves. Viewing windows and screens are not PPE.

A14.27 Protective housing
Those portions of a laser product (including a product incorporating an embedded laser) that are designed to prevent human access to laser radiation in excess of the AEL prescribed for the product. (The laser product manufacturer generally installs the protective housing.)

A14.28 Pulsed laser
(As defined in EN 60825-1) a laser that delivers its radiation output in the form of pulses with duration less than 0.25s, either singly or a train of pulses.

A14.29 Pulse Repetition Frequency (PRF)
The number of pulses per second emitted by a pulsed laser.

A14.30 Radiance
The radiant power per unit area of a radiating surface per unit solid angle of emission ($Wsr^{-1}cm^{-2}$).

A14.31 Radiant exposure
The radiant energy incident on an element of a surface divided by the area of that element (Jcm^{-2}).

A14.32 Specular reflection
Reflection from a shiny surface, such as a mirror.

A14.33 Standing Orders (SO)
A set of formal written instructions that address all hazards and procedures for a specified location or piece of laser equipment.

Appendix 15. Training

Role	Initial Training	Refresher	Frequency	Comments
LRO/OLRO	LRO/OLRO Initial training (1 day) and LNP Basic Laser Course (1/2 day)	LRO/OLRO Refresher training (½ day)	3 years	Training to be consistent with TR 50448 'Guide to levels of competence required in laser safety' plus a review of current laser safety standards.
Courses Available:	Pro Laser – LRO/OLRO Initial training (1 day) Pro Laser – Laser Safety Awareness training [Basic Laser Course] (½ day) Pro Laser – LRO/OLRO Refresher training (½ day)			
LNP	Basic Laser Course (½ day) or Verbal briefing from LRO appropriate to level and range of duties	Basic Laser Course (½ day) or Verbal briefing from LRO appropriate to level and range of duties	3 years	Training to be consistent with TR 50448 'Guide to levels of competence required in laser safety' for laser users.
Courses Available:	Internal SHE Group (½ day)			
Users of Low Risk lasers	Verbal briefing from LRO	Verbal briefing from LRO	3 years	Training should cover the effect of laser radiation on the eye and the importance of preventing direct eye exposure.
Courses Available:	None specific to Low Risk laser use			

Formal or on-the-job training for any of the above positions prior to appointment may be necessary, but is not a prerequisite for persons with adequate experience.

Appendix 16. Audit Checklist

Ref	Item	Rating	Comments
1 (Section 4.4.11) (Appendix 5.1.1) (Appendix 8) (Appendix 13)	Do all the laser sources have the appropriate classification and warning label(s)?		
2 (Section 4.4.7) (Appendix 5.3.1.3) (Appendix 11)	Have documented risk assessments been undertaken for activities involving High Risk lasers?		
3	Have these risk assessments been recorded in SHE Enterprise?		
4 (Section 4.4.10) (Appendix 5.3.1)	Have control methods implemented for activities involving High Risk lasers been based upon risk assessment?		
5 (Section 4.4.8) (Appendix 6) (Appendix 7)	Is all work with High Risk lasers undertaken within Designated Laser Areas?		
6 (Section 4.4.9) (Appendix 5)	Have the default controls been fully implemented for activities involving Class 1M, 2M, 3R and Embedded lasers?		
7	Is documentation as laid out in Appendix 12 available?		
8 (Section 4.4.21)	Are permits to work on lasers signed off correctly?		
9 (Section 4.4.3) (Section 4.4.7) (Section 4.4.14)	Do Standing Orders for work with High Risk lasers adequately address all hazards and use of PPE?		
10	Has an audit of all Designated Laser Areas been undertaken within the last 18 months?		
11 (Section 4.4.12)	Is there evidence that laser safety eyewear is in use where appropriate?		
12 (Section 4.2.4)	Have all laser users been adequately trained?		

(Section 4.3.7) (Section 4.4.3) (Section 4.5.3) (Appendix 15)			

Appendix 17. Bibliography of laser safety references

EN 60825-1: 2007. Safety of laser products. Part 1: Equipment classification and requirements.

EN 60825-2: 2007. Safety of laser products. Part 2: Safety of optical fibre communications systems.

IEC 60825-3 Safety of laser products, Part 3: Guidance for laser displays and shows.

PD IEC TR 60825-14: 2004 Safety of laser products, Part 14: A user's guide.

PD CLC/TR 50448: 2005 Guide to levels of competence required in laser safety.

EN 207: 1999. Filters and Equipment used for Personal Eye-Protection Against Laser Radiation

EN 208: 1999. Personal Eye-Protection Used for Adjustment Work on Lasers and Laser Systems.

AURPO Guidance Note No 6 'Guidance on the safe use of lasers in education and research' 2006

'Laser Safety' Henderson, R. Schulmeister, K, Institute of Physics 2003 ISBN: 0 750 30859 1 http://www.laserinstitute.org/store/LSAFPUB/301

Sliney, D. Wolbarsht, M., Safety with lasers and other optical sources. Plenum Press, New York, 1980.

The radiation safety of lasers used for display purposes - Health & Safety Executive publication HS(G)95 1996 ISBN 0 7176 0691

The International Commission on Non-Ionising Radiation Protection (ICNRP) publications. http://www.icnirp.org/pubOptical.htm

Optical Radiation Directive, published in the Official Journal of the European Communities on 27 April 2006 (Ref: L114) "Directive 2006/25/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (artificial optical radiation)"

Laser Safety Management. Kenneth Barat. CRC, Taylor & Francis, 2006 ISBN: 0 824 72307 4 http://www.laserinstitute.org/PDF/pubs/pub209toc.pdf